Effects of school toothbrushing programs on caries experience

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1 DECLERATION BY AUTHOR

I, Tony Cakar of Brisbane, Queensland, do solemnly and sincerely declare that these research project reports have been composed by myself and have not been accepted in part or in full for another degree. I make this declaration conscientiously believing the same to be true before a Justice of the Peace.

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5 INTRODUCTION AND BACKGROUND TO RESEARCH

Dental caries is one of most challenging conditions in children, with almost half of Australian children experiencing caries by the age of 6.[1] The highest incidence of caries is experienced by low socio-economic communities, immigrant or indigenous populations and medically compromised patients.[2, 3]

Untreated dental caries is associated with considerable morbidity. It can result in chronic pain, difficulty in eating and drinking as well as loss of sleep, behavioural problems and reduced quality of life. [4, 5] Furthermore, untreated carious lesions commonly progress to oral abscesses which can have serious consequences and are the most common reason for preventable hospital admissions in children. [6]

The cost of treating dental caries is staggering, with the direct costs of over $6 billion dollars, making oral disease the second-most expensive disease group in Australia.[7] Furthermore, the cost of treating caries in children and particularly early childhood caries (ECC) is very high as treatment under general anaesthetic (GA) is almost routinely required. This is due to the severity of the disease, complicated and aggressive dental treatment that is often necessary and the fact that the young child is often uncooperative for treatment in the dental chair. [8, 9] The success of rehabilitation may be questionable, with some children requiring hospitalisation for new lesions as early as six months post GA treatment. [10, 11]

The reported burden of caries in children includes personal, familial and social costs and is likely to be under-reported. The cost of treating dental caries is not limited to the public cost of hospitalisation and treatment. It also involves associated out-of-pocket costs to the family (such as travel costs, time off work and costs of medications) and social costs to the child including diminished quality of life due to pain and discomfort as well as absence from school. [6, 12, 13]

Dental caries is largely preventable. [14] At the community level, several studies show successful reduction in caries rates through community prevention programs such as targeted school based toothbrushing programs.[15-18] However, very few studies have been conducted to evaluate the cost-effectiveness of caries prevention programs for children and associated quality of life issues. [19, 20]

This research will focus on a single community based prevention strategy – toothbrushing at school programs; and will be based on the following hypothesis:

1. A primary school toothbrushing program is effective in reducing caries experience in children
2. A primary school toothbrushing program is a cost effective strategy for reducing caries experience in children

Hence the aims of this report are to critically review the literature and identify gaps in knowledge with respect to:

1. The effectiveness of school toothbrushing programs for prevention of caries in children
2. The health economics of caries prevention programs for children including cost effectiveness and oral health related quality of life gains and losses.

6 LITERATURE REVIEW

6.1 Aetiology of caries and the role of toothbrushing

The aetiology of caries is multifactorial and depends on a complex interplay of biological, physiological, psychological and social factors. In a landmark report in 1969, Keys[21] represented dental caries diagrammatically as an interplay between bacteria, diet and tooth. Since then the diagram has been used ubiquitously in explaining caries mechanisms; with a number of amendments to include additional factors important in aetiology such as time, saliva, behaviour and education.[22]

In simplified terms, the caries process results when acidogenic oral plaque bacteria ferment carbohydrates that are taken into the mouth, thereby producing organic acids which diffuse into the tooth enamel, dentine or cementum to partially dissolve the hydroxyapatite mineral crystals.[23, 24] Calcium and phosphate diffuse out of the tooth, eventually leading to cavitation if the process continues. In favourable conditions, demineralisation can be reversed by calcium, phosphate and fluoride diffusing into the tooth and depositing a new veneer on the crystal remnants in the non-cavitated lesion.[25] The process of demineralisation and remineralisation generally occurs numerous times per day, leading either to cavitation, repair and reversal or maintenance of the status quo.[23, 24]

Toothbrushing has an effect on both bacteria and tooth through a number of complementary mechanisms to control caries. Mechanical nature of toothbrushing acts to remove or reduce bacteria from the tooth surface and disturb the organised nature of dental plaque.[26] Toothpastes, which are commonly used during toothbrushing, are vehicles for active ingredients such as fluoride, triclosan and sodium lauryl sulphate, that have been shown to have a number of positive effects including improving tooth surface characteristics by decreasing demineralisation and increasing remineralisation,[25] as well as direct anti-bacterial effects.[27]

6.2 Modes of action of toothbrushing to control caries

Brushing teeth with a fluoride toothpaste two times a day still remains the most effective caries preventative measure;[28] and a number of synergistic modes of action of toothbrushing to control caries have been proposed.[26] However, there is still debate in the literature as to the importance of each mode of action.[29, 30]

6.2.1 Mechanical plaque removal

Mechanical plaque removal aims to eliminate and reduce the number of cariogenic bacteria from the tooth surface thereby reducing the likelihood of caries development and progression.[26] However, from a microbiological standpoint the tooth is never truly clean and the amount of plaque removed is highly dependent on the skill and efficiency of the individual as well as the tooth surface.[26] For example, hypoplastic areas,[31] as well as the fissures and proximal surfaces are likely to retain more plaque.[32, 33] Early studies have shown that even after careful toothbrushing and flossing, residual plaque still has the ability to elicit a moderate pH drop after a carbohydrate challenge.[34] None the less, numerous studies have shown the association between the accumulation of dental plaque and caries development in children,[35] and conversely removal of plaque by toothbrushing a child's teeth twice a day from the age of one, has been shown to significantly reduce the chance of caries development.[36]

6.2.2 Plaque disruption

As toothbrushing cannot provide complete bacterial removal, some of its caries inhibiting effect may be attributed to plaque disruption. The key features of all biofilms, including dental plaque, are increased virulence and improved resistance to antimicrobials compared to the same bacteria in planktonic form.[37, 38] It has been observed that as plaque matures, the voids and channels which are commonly present in young dental plaque are lost.[39] This may explain the findings that seven day old plaque has restricted penetration of 1000 ppm fluoride solutions,[40] thus suggesting that the anti-caries effect of fluoride toothpastes may be reduced when oral hygiene is poor.

Although it still remains unclear at what developmental stage plaque becomes cariogenic, an early study has demonstrated that dental plaque must be at least 2 days old before the acid formation in response to sucrose challenge is sufficient to cause demineralisation of enamel.[41] Furthermore, as plaque matures the overall number of bacteria increases and may become less diverse.[42] Therefore, it could be argued that under the right conditions, mature plaque may contain a higher overall number of acidogenic bacteria and therefore have the potential to have increased cariogencity. However, this reasoning is somewhat oversimplified, as a complex interplay of bacteria in biofilms can also have competitive and antagonistic effects.[43]

6.2.3 Removal of cariogenic bacteria

Simple instruction in correct toothbrushing techniques has been shown to produce a marked *S. mutans* reduction in children.[44] This effect may be partly attributed to an overall reduction in bacterial counts after toothbrushing, due to the physical removal and disruption of bacterial biofilms . On the other hand, toothbrushing is commonly performed with toothpastes, which contain a number of agents that have been shown to inhibit the growth of cariogenic bacteria.[27, 45-49] In particularly, the anti-mutans activity of sodium lauryl sulphate,[27] may explain the clinical findings of low to zero levels of *S. mutans* after the commencement of toothbrushing with children's toothpaste.[50] Increasing the frequency of brushing to twice daily significantly reduces the number of *S. mutans* positive children.[51]

6.2.4 Additives in toothpaste

The key additives in toothpaste, which have been shown to have a positive effect on caries experience in children, will be discussed below.

Fluoride

Fluoride, in its many forms, is ubiquitously accepted as the most successful agent for caries reduction over the last 60 years.[25] Fluoride toothpastes are arguably the most widely used and easily accessible topical fluoride product around the world,[52] and have been shown to be highly

effective anti-caries agents.[53] Their main advantages are that there is no additional compliance to toothbrushing together with accessibility and relative affordability.[54] Significant decrease of world wide caries rates have been linked to addition of fluoride to toothpastes.[55].

Fluoride delivers an anti-cariogenic affect through multiple synergistic mechanisms:[56]

Reduction of demineralization

Fluoride reduces enamel demineralisation by decreasing the solubility of hydroxyapatite and increasing its resistance to an acid challange.[57 58]
Exposure of dental enamel to fluoride promotes the exchange of the hydroxyl ion for the fluoride ion creating less soluble fluorapatite or fluoride hydroxyapatite rather than hydroxyapatite.[59]

Furthermore, fluoride inhibits demineralisation of enamel via its ability to bind calcium and phosphate, which are dissolved by acid attack on enamel appetite crystals. [59] This binding prevents the mineral constituents of the enamel being leached away into the plaque and saliva [60, 61] In 1983 Ten Cate and Duijsters[62, 63] determined that the amount of mineral lost during demineralisation is a function of both pH and fluoride concentration. They found that the greatest inhibition of mineral dissolution occurred at the fluoride concentration where the solution was supersaturated with respect to calcium fluoride.

Promotion of remineralisation

The development and progression of dental caries is a dynamic process between demineralisation and remineralisation.[22] Remineralisation occurs when fluoride, phosphate and calcium ions diffuse into the lesion and rebuild the partially demineralised hydroxyapatite crystals into fluorohydroxyapatite.[53] The resultant crystals are stronger and more resistant to demineralisation than the original ones.[64, 65] The application of fluoride containing agents to the oral cavity provides a reservoir of available mineral to enable the intraoral equilibrium to tend towards remineralisation and away from demineralization. [64] Furthermore, post eruption maturation of enamel is aided by fluoride, which if available, readily incorporates into the enamel surface [66, 67].

On the other hand, when acidogenic bacteria cause demineralisation of enamel, the enamel surface becomes more porous which in turn promotes fluoride remineralisation.

Inhibition of bacterial function

It has been proposed that fluoride has direct and indirect effects on bacterial metabolism including acidification of bacterial cytoplasm and by binding key metabolic enzymes such as enolase and ATPase.[45-48] However, antimicrobial action of fluoride in vivo has been questioned, as in vitro experimental effective levels of fluoride are much higher than would be clinically applicable (<10,000 ppm depending on the pH).[68, 69] As such it is not surprising that fluoride levels found in plaque after application of 1,500 ppm fluoride toothpaste have not shown any antibacterial effects.[70]

Sodium lauryl sulphate

Sodium lauryl sulphate (SLS) is the most commonly used detergent in commercial toothpastes. It has been shown to reduce extracellular polysaccharide formation as well as lactate production by *S. mutans*.[71, 72] It also impairs the formation of salivary pellicle, thereby delaying bacterial adhesion and plaque formation.[73] Previous in vitro studies have shown an antimicrobial effect on a range of bacteria including mutans streptococci.[74] A recent in vitro study has shown that SLS, in both 500 ppm and 1000 ppm fluoride toothpastes, has an inhibitory effect on the growth of *S. mutans, S. sanguinis and L. acidophilus*. This finding supports previous studies that have reported low to zero *S. mutans* levels after commencement of brushing with children's 500 ppm fluoride toothpastes,[50] and significantly lower *S. mutans* levels in children who brushed two times per day compared to those who brushed less frequently.[51]

Triclosan

Triclosan is an antimicrobial agent commonly added to toothpastes, with a broad spectrum against both gram positive and negative bacteria.[49] It is believed that it exerts its action by

disturbing bacterial cytoplasm membranes and blocking fatty acid biosynthesis.[75] However, due to its low substantivity and poor water solubility,[76] it has shown to have a modest effect on dental biofilm.[77] In order to improve these properties, commercial toothpaste manufacturers have added a copolymer of polyvinylmethylether/maleic acid (PVM/MA), giving reportedly enhanced substantivity and anti-plaque efficacy.[75, 78] However, some authors have raised concerns over the use of triclosan in toothpastes due to its likely dilution to sub-lethal concentrations when mixed with saliva in the mouth, which may promote bacterial resistance or co-resistance to other antimicrobials.[79]

Others- flavours, anti calculus agents, humectants and abrasives

Xylitol and sorbitol are flavour enhancers which are commonly added to toothpastes. In vitro studies have shown minimal effects against *S. mutans, S. sanguinis and L. acidophilus*,[27] which likely due to the minimal metabolism of xylitol and sorbitol by these bacteria.[80, 81] Other agents such as sodium pyrophosphate (an anti-calculus agent), and polyethylene glycol (a humectant), have been shown to reduce bacterial adhesion to enamel and therefore delay plaque formation.[82-84] On the other hand, abrasives, binders and fillers are thought to have minimal antimicrobial effects,[27] although these agents may theoretically improve the removal of plaque especially tenacious or stubborn stains which would otherwise promote further adhesion of bacteria.

6.2.5 The effect of frequency and timing of toothbrushing on caries experience in children

The frequency of toothbrushing has been linked with caries experience in children. Children who brush their teeth less than twice a day have a greater likelihood of developing caries within the ensuing twelve months.[36, 85, 86] Although brushing once a day, if done perfectly, should theoretically be sufficient to sustain a healthy dental environment, most laypeople are not able to achieve such a result and this is why brushing twice daily is generally advised.[87]

Supervised toothbrushing and parental toothbrushing of a child's teeth, increases brushing effectiveness as the child does not have the adequate dexterity skill until the age of nine year.[88, 89]

The timing of toothbrushing is also important as salivary flow and its protective benefits are reduced during sleep therefore the brushing before bed is essential for caries prevention.[90]

Recommendation

Parents should begin cleaning their children's teeth with a toothbrush, as soon as eruption occurs. Brushing a child's teeth twice a day from the age of one year has been reported to double the child's chances of remaining caries free.[36]

6.2.6 Gaps in knowledge

The effectiveness of mechanical plaque removal alone in caries control has not been extensively researched as the literature commonly examines the combined effect of toothbrushing with fluoride toothpaste. This has lead some authors to question the role of toothbrushing *per se* in caries control, noting that many patients with poor oral hygiene do not experience caries; and further stating that it is fluoride in the toothpaste rather then the biofilm removal which provides an anti-caries effect.[29, 30] This point is unlikely to be clarified in the future as the use of fluoridated toothpaste is common practice in most of the world and forms part of most dental guidelines.

An early study compared the effect of supervised toothbrushing with and without fluoridated toothpaste on 9-11 year olds over a 3 year period, noting that there was no significant caries protective effect of brushing with a non-fluoridated toothpaste compared to a highly significant effect of brushing with a fluoridated one.[91] No such study has been undertaken to involve the primary dentition.

6.3 School toothbrushing programs

6.3.1 School based programs

In order to improve the health of students, families and communities, in 1995, the World Health Organization launched the "Global School Health Initiative",[92] targeting a number of health issues including nutrition, tobacco use, HIV and in 2003 specifically oral health.[93] The rationale behind targeting health promotion to school children is that world wide attendance rates primary schools is high,[94] thus a substantial part of the child population can be reached this way. Furthermore, schools are an import part of child's socialization and development, and during the school years lifelong sustainable health related behavior, beliefs and attitudes can develop. Primary school children are particularly receptive during this period and the earlier the habits are established, the longer lasting is the impact.[92] Moreover, the messages can be reinforced regularly throughout this period .

Although brushing at home twice a day is optimum, many children, particularly in low socio-economic areas, do not do this.[95] School-based interventions not only offer children supervised brushing once a day, they also offer training in a skill that has the potential to be continued in the future, and which may not be being taught at home.[96]

6.3.2 Worldwide trends

A recent WHO global survey of school-based oral health promotion in 61 countries of various geographic and economic backgrounds, revealed that after oral health education, daily toothbrushing at schools was the most common intervention used today.[97] The paper could not assess the quality and consistency of the actual implementation of programs, however, it provides a global overview of the type of oral health prevention activities carried out by schools.

A number of countries have adopted school based toothbrushing as part of national health programs. For example, the Brazilian Heath System funds supervised toothbrushing across several major cities. [98] On the other hand, supervised kindergarten and primary school

toothbrushing is the main component of the Childsmile, Scottish national oral health improvement program, which began in 2006.[99]

6.3.3 Current evidence of effectiveness

Despite the WHO recommendation that the school oral health programs should be periodically evaluated for effectiveness and outcomes measured,[93] the current evidence shows that this is exceptionally rare.[97] To date, there have been only seven original studies published examining toothbrushing at schools as the key element of the intervention (one RCT, four longitudinal and one cross-sectional).[15-18, 100-104] Additionally, one study has integrated toothbrushing as part of general health promotion,[105, 106] and another study has utilised school toothbrushing as a control to assess the effectiveness of cross brushing by trained dental assistance five times per year to prevent caries in newly erupted first permanent molars.[98] Furthermore, there have been two Australian toothbrushing programs, which have not been formally evaluated.[107, 108] Table 1 summarises the recently published studies.

Successful Programs

The four studies with that have shown the best outcomes have been the Scottish,[16, 17, 102] UK[18], Chinese[109] and Jordanian[15]. The Scottish school toothbrushing program, ran for 30 months, targeting 5 year old children in a disadvantaged, non-fluoridated area and showed a 32%-56% reduction in caries affecting the fist permanent molar.[18, 102] A 6 year follow up showed a sustained caries reduction of 20%–26%.[17]

The London study targeted 517 primary school children (mean age 5.6 years) in a non-fluoridated, disadvantaged area with teacher-supervised toothbrushing with fluoride toothpaste (1,400 ppm).[18] Even though the study didn't provide toothpaste and brushes for home use and had no involvement with the parents, it still reported reductions in tooth decay of 11%-21% over the 21 month period compared to control schools.[18] It is not known, however, if the impact was sustained after the study finished.

A Chinese study, targeted 258, 3-year-old children in test kindergartens who received monthly oral health education by dental professionals and performed toothbrushing at school two times a day with a 1100 ppm fluoride toothpaste.[109] The children's parents received oral health education two times a year but no toothbrushes or toothpastes were provided for home use. The study reported a reduction in dmfs increment of 30.6% (dmfs 2.47 in study group and 3.56 in control group $P < 0.009$)

Furthermore, the Jordanian study, which ran for four years and involved 436 primary school children showed that 6 year old children participating in the program were six times less likely to develop caries compared to controls.[15] The children brushed their teeth once a day with a 500 ppm Fluoride toothpaste, while under supervision of a teacher. The children lived in a low socio-economic area, which was fluoridated ideally for the climate (0.5 ppm).

Integration of toothbrushing at schools with other health programs showed initial success in the Filipino Fit for School study.[106] During the program, daily toothbrushing, with older children supervising younger children, was combined with hand washing and biannual deworming. A year follow up failed to show statistically significant reduction in caries, however, it did show significant reduction in soil transmitted helminthes infections and a rise in mean BMI.[105] The study reported variable adherence to toothbrushing protocol which is likely the reason for the limited success.

Programs with limited success

The studies that have shown limited success in reducing caries or limited sustainable effects through toothbrushing at schools have been a Dutch[104] and a resent Chinese[101] intervention. The Dutch study which ran for 3 years involving teacher supervised toothbrushing at schools showed improvement in toothbrushing frequency in 7-10 year old children.[104] However, one year after the intervention the toothbrushing frequency returned to baseline. The study did not measure caries experience. The authors attributed the failure of the study to the fact that the toothbrushing frequency at baseline (two times per day) was acceptable and further benefit of additional toothbrushing at school is unlikely.[104] However, the ceiling effects of toothbrushing frequency has not been extensively researched by the literature.

The Chinese study was a three year toothbrushing at school program, which showed significant impacts on gum health, reduced sweet food consumption, increased parental and teacher oral health knowledge; however it failed to show statistically significant improvement in caries rates.[101] The failure of the study was though to be attributed to limited uptake of toothbrushing at schools with only half of the children participating.

There are two Australian toothbrushing at school programs which have reported limited success. The results of these studies have not been published in peer reviewed journals. The Victorian program targeting a rural aboriginal community, reported initial positive improvement in toothbrushing frequency. [108] However, after the key champion person, who promoted the program, left the school, the toothbrushing practices were not sustained. On the other hand, the Queensland's 'Toothbrushing in Primary Schools' (TIPs) project targeting 5 year old children 14 primary schools in Brisbane Bayside area, showed no statistical significant difference in caries experience between case and control groups after 3 years.[103] The project attributed the failure of the study to the use of low fluoride toothpaste (500ppm) in a non fluoridated area. This point is still open to debate and will be discussed further below.

6.3.4 Determinants for a successful school toothbrushing program

In a comprehensive review of evidence-based oral health promotion, Rogers,[110] outlines a number parameters which are common to the successful toothbrushing at schools programs:

1. High base line caries experience in the community
2. Non-fluoridated communities
3. Children are not brushing twice a day at base line
4. The programs target young children in primary schools (from 5 years old)
5. There is support for teachers
6. The programs are sustained
7. There are links with parents

Current available evidence shows both agreement and some divergence from the above points. A number of studies have shown that school based toothbrushing programs are particularly effective in low socio-economic areas,[15, 18, 99, 100] where toothbrushing rates at baseline are generally low and caries experience is high.[1, 111] However, the Scottish national survey of the

'Childsmile' program has shown that school toothbrushing has a significant positive effect in high socio-economic areas, however, the effect is smaller (mean dmft decreased from 1.52 to 1.10 in high SES area compared to 4.48 to 2.77 in low SES area).[99]

On the other hand, the World Health Organisation supports Roger's argument of targeting young children in primary schools as they are particularly receptive during this period and the earlier the habits are established, the longer lasting is the impact.[92] Furthermore, the chance for prevention is greater in younger years as the disease is less like to have already occurred. All of the successful programs have integrated training for teachers as part of their program and run for two years or more. Parental involvement is part of some, but not all programs.

Moreover, Rogers,[110] argues that the toothbrushing at schools programs are most successful in areas without optimum water fluoridation. This can be theoretically explained as non-fluoridated areas are expected to have higher caries experience and therefore be relatively more responsive to preventative programs. However this has not been experimentally demonstrated as all of the successful and non successful programs have been undertaken in low water fluoridated areas.

Rogers, [110] further argues that the fluoride content of the toothpaste used in the school programs may need to be increased in non-fluoridated areas; noting that the failure of Queensland's TIPS project may be attributed to use of child-strength toothpaste by the study. [110] A recent Cochrane review in effectiveness of varying strengths of fluoride containing toothpaste in preventing dental caries in children and adolescence, supports such a view, concluding that fluoride containing toothpastes have caries preventative effect only at concentrations above 1000 ppm.[112] The authors, however, warn that the risk of fluorosis should be taken into the account when adult strength toothpaste for children below the age of 6 is recommended.[112] The issue is complicated by the fact that the Australian Dental Association guidelines state that children under the age of 6 should use child strength toothpaste (400 – 550 ppm fluoride) unless on advise of a dentist;[113] and a number of recent Australian studies using the recommended child strength toothpastes have shown very positive improvements in caries experience of young children.[51, 114, 115]

Interestingly, only one of the published study examining toothbrushing at schools uses 500 ppm toothpaste for a test group of students (mean age 6.3 years SD 029) in a fluoridated area.[15] The

study showed that children in the test group were 6.4 times less likely to develop caries than the control group. All of the other studies both successful and unsuccessful use 1000 ppm or greater toothpaste.

It is also worthwhile noting that access to toothbrushes and toothpastes as well as infection control can be potential barriers to provision of toothbrushing at schools programs.[110] Provision of toothbrushes, toothpastes and storage cases can easily overcome access issues. Infection control issues can be overcome by provision of clear infection control guidelines and regular auditing for compliance, by oral health staff. [16, 17, 102] A further point that should be considered is that toothbrushing programs can successfully linked to other health programs [106] and be a useful entry point to engage children, schools and the community with dental health services.[107]

6.3.5 The Logan Beaudesert School Toothbrushing program

The Logan-Beaudesert area in Queensland is a very low socioeconomic region with high immigrant and transient populations.[2, 3] As previously mentioned, the area has one of the highest rates of caries in Australia, with over 78% of 6 year old children affected.[1] Community water fluoridation was introduced to the area in 2009, giving a unique opportunity to study the effects on water fluoridation and its interactions with other prevention strategies. The effects of water fluoridation on school toothbrushing prevention program has not been studied to date.

A toothbrushing program has been implement in the primary schools in the Logan-Beaudesert area for over a decade as part of standard Queensland Health practice. Due to the large number of schools relative to health promotion staff in the area, only some of the schools in the district can participate in this program.

In the toothbrushing program the participating schools receive a start-up lesson for teachers and students at the beginning of the year, conducted by Oral Health Staff. This lesson outlines the rules of the program. The participating children are provided with a toothbrush, toothpaste and a case for storage of the brush and paste; which is held in their desks for the duration of the school term. The teacher supervises daily toothbrushing of students when they are at school. The entire class brushes together, at the same time, each day. After brushing, children rinse the toothbrushes which are then stored. All grades (from prep to year 7) participate in the study. The Australian

Dental Association guidelines are followed for fluoride content of the toothpastes provided to the children.[113] The participating schools are audited by oral health therapists twice yearly for adherence to protocol and for infection control.

All children attending schools in the Logan Beaudesert area are eligible for free dental services including examination and treatment. Clinical data related to dental treatment are collected for every school including parental consent to treatment per grade, caries experience (dmft) and treatment provided. The data are available for all schools including those which are not participating in school toothbrushing program and are kept at the central office at Kingston Oral Health Centre. The effectiveness of the school toothbrushing program in the Logan-Beaudesert area has thus far not been investigated.

The key advantages of the Logan-Beaudesert primary school toothbrushing program are that the intervention is part of standard Queensland Health practice and has been sustained for over a decade, there is continual support for the teachers from the oral health staff, the program targets young children in primary schools starting from prep year (mean age 5 years old), and the children in the program live in a very low socio-economic area with high base line caries experience. The key disadvantage of the program from a research perspective, is that it was not originally established as a prospective randomized trial, therefore only retrospective analysis of available data can be performed in order to evaluate its effectiveness. Furthermore, there is limited involvement of the children's parents in the program.

6.4 Health economics of caries in children

6.4.1 Cost Effectiveness

The evaluation of cost effectiveness, including quality of life gains and losses, of prevention programs is extremely important for their sustainability.[116] This information allows policy makes to construct informed decisions in order to achieve best patient outcomes.[117] Unfortunately, there are no studies to date, that have evaluated the cost effectiveness of school toothbrushing programs, with very few studies that have evaluated cost effectiveness of other prevention programs for caries in children.[19, 20] A recently published, Australian first, study in cost effectiveness for ECC prevention found that a telephone intervention program targeting new mothers in Logan-Beaudesert area, was highly cost saving for public oral health services.[118] The study showed that 43 dental caries can be prevented for every 100 children with an estimated saving of 69,984 pounds for the public oral health services.[118] These findings are similar to an earlier Californian study which evaluated ECC prevention programs for low-income households and found that an intervention consisting of an examination, fluoride varnish application and parental counseling achieved 70% reduction of caries at a cost of US$66 per caries surface prevented.[119]

Several other caries prevention programs in children have shown cost savings with Savage,[120] finding that the earlier a child attends the preventative services the lower the costs. Hirsch,[121] identified through simulation modeling, that the greatest cost-benefit was seen in interventions targeting the youngest children with the greatest caries risk. Furthermore, Kowash,[20] found that the long term home-visiting program was more successful than traditional interventions.

Cost modeling

Measuring true cost savings though prevention programs can be difficult as cost analysis requires a multitude of clinical disease states and associated costs including treatment costs for all management possibilities, out of pocket costs to families and quality of life gains/losses for

children.[122] The disease risk is also continuous, however, it may change over time.[122] For these reasons the cost-savings of prevention pragmas are likely oversimplified and underestimated.[116, 118, 122] A health state transition model such as the Markov model,[123] addresses one of the challenges of varying health states over time. It has been previously utilised in assessing effectiveness of caries prevention programs in Australia.[118, 124] Models assume that a patient is always in one of a finite number of discrete health states: 'healthy' and 'caries'. The children can move between the states periodically. For example, a child who has caries may be treated (move to healthy state) and subsequently may develop recurrent caries or remain caries-free. By analysing the observed movement of children thought the health states, the Markov model can estimate the incidence of caries and costs of control and intervention groups.[123]

6.4.2 Health Related quality of life

Overview

Health related quality of life (HRQoL) belongs to the theoretical, biophsychosocial model of health in which symptoms, physical functioning and emotional and social well-being are incorporated.[125] It is the subjective evaluation of the individuals health and how this state affects the individual physically and emotionally, which is dependant on the individual's cultural and social norms.[125]

Since the WHO defined health as a complete state of physical , mental and social well-being and not just the absence of disease",[126] there has been an insurgence of medical and dental literature on health related quality of life and the quality of life issues have become at the forefront of public health policy.[127]

The focus on health related quality of life issues in research and policy making has also seen a shift from traditional health care to one which focuses of the person's social and emotional experiences and physical functioning to assess the intervention goals and outcomes.[128] Improvements in quality of life is becoming an important outcome for health care provision as it is recognised that patient satisfaction is likely to impact on health related decisions, behaviours, utilisation of services and motivation to seek care and compliance [129]

General health

Effect of pain from chronic medical conditions on quality of life has been extensively studied.[130-132] For example, children who suffer from headaches are more sensitive to pain, cry more during routine medical visits, avoid play and games because of fear of self-injury and have more frequent abdominal pain and growing pains.[131] On the other hand, children with cerebral palsy and chronic tonsil and adenoid disease suffer poorer quality of life than healthy children.[130, 132] Furthermore, facial deformity prior to surgery plays a great role in social interactions of children and following surgery there is an improvement in social functioning and quality of life[133]

Oral health related quality of life and caries in children

Oral health related quality of life can be studied in diverse populations and for multiple oral conditions. A number of studies have shown that facial trauma,[134] cranio-facial deformities,[133, 135] and orthodontic problems [136-138] impact negatively on children's quality of life. Children from low income families[137, 139] and those with mothers that suffer from dental anxiety[140, 141] have been shown to experience lower oral health related quality of life.

Untreated caries in children and its effects on quality of life has been researched by a number of authors; all stating that it significantly and negatively impacts on the child's quality of life.[127, 135, 136, 142-168] The untreated caries in children can result in pain, systemic infection and abscesses [111] but can also lead to more widespread health issues including hospitalizations and emergency room visits [162], delayed or insufficient physical development,[145, 169, 170], loss of school days and increased days restricted activity [171, 172] as well as diminished ability to learn.[173] Furthermore, frequent school absences, inability to concentrate in school, reduced self-esteem, poor social relationships can result from dental caries or related pain [174] Lost workdays for caregivers who have to stay at home to take care of their child, or spend time and money in accessing dental care have also been associated with children suffering from untreated dental caries.[171]

Adverse effects on growth of the body (body weight and height) and failure to thrive have been attributed to early childhood caries by several studies. [145, 169, 170] A Canadian study showed that children with severe cares weighed less than controls and that after treatment, the children showed a rapid weight gain and improvement in their quality of life.[161] However, an earlier US study contradicted these findings by showing that children with severe dental caries did not weigh on average below the 50th percentile and the slight, non significant gain in percentile weight following dental rehabilitation under GA was not indicative of a "catch-up growth"; however there was a significant improvement in the children's quality of life as reported by their parents [175]

Decayed, missing, filled teeth index (dmft/DMFT) and OHRQoL

Throughout Queensland Health facilities, the burden of oral disease is reported by the use of clinical measurements; primary the dmft/DMFT index. This type of data collection has been traditionally well utilised by the oral health staff as it is standardised and relatively simple to apply.

However, these data provide limited insight into the consequences of the oral disease for the children's lives. [176] Therefore, oral health quality of life assessment has been recommended as a complementary tool for better understanding of the impact or oral health problems on the individual's daily performance and may be a better instrument for communicating with policy makers responsible for planning oral health programs and providing access to care.[177]

Measuring quality of life – quality of life questionnaires

In the recent years, much of the research has been devoted to development and testing of new quality of life scales among convenience samples.[163] There has been a number of instruments developed with recent review identifying 14 generic paediatric quality of life scales and many more condition specific scales.[178] Jokovic,[135, 179-183] has laid the foundation for the literature on children's OHRQoL with development of Parental Caregiver Perceptions Questionnaire (P-CPQ) and the Family Impact Scale (FIC). These instruments consist of series of questionnaires related to three different age groups 6-7, 8-10, 11-14 years old, and are based on earlier generic questionnaires; namely the Parent form of the Child Health Questionnaire (CHQ) [184] and Infant Toddler Quality of Life Questionnaire (ITQOL).[185]

This research was the basis for the development of multiple other scales including the Child Oral health Impact Profile (COHIP), [163, 186, 187] and the Michigan Oral Health Related Quality of Life Scale.[148] However, the most significant of these has been the Early Childhood Oral Health Impact Scale (ECOHIS).[158] The questionnaire was originally developed for assessing OHRQoL for 3-5 year olds and was based on 45 original items by Jockovic, [182] which were simplified by consulting 22 health professionals and 30 parents into 13 key items which were then tested on 295 children. The ECOHIS has since been most widely utilised and validated across the globe, for assessment of paediatric OHRQoL.[140, 142, 154, 167, 188, 189]

Although a number of previously developed scales, including the P-CPQ, COHIP and ECOHIS, have shown validity in measuring relative, qualitative, OHRQoL differences with varying disease states and effects of interventions, none of these instruments have been developed as utility scales, where quantitative weights are attributed to OHRQoL and the respective health states. Therefore, direct comparisons between studies as well the direct application of the existing scales on previously collected clinical data to retrospectively ascertain OHRQoL has been impossible.

To this date, only a single, multi attribute utility instrument, the University of Sheffield CHU-9D has been validated.[190] This is a generic paediatric health utility instrument based on the UK population. Therefore, a specific oral health related instrument will need to be developed in referenced to the CHU-9D with an assumption that the UK utility weightings are comparable to Australian children.

Parents as proxy for answering OHRQoL questionnaires for young children

Literature on child development and psychology indicates that children younger than 6 years of age are unable to accurately recall everyday and unique events beyond 24 hours.[191, 192] Children begin to reason about the timing of past event with respect to the day of the week, month or season at the age of 7 or older.[193] Furthermore, at approximately 6 or 7 years old, children become capable of abstract thinking, which is important for understanding the concepts of health and disease.[192] Therefore, it is not surprising that the research that has attempted to use preschool age children as respondents in QHRQL has been met with limited results.[148] Furthermore, it could be argued that measuring parent's perception about how disease and its treatment influences their child's quality of life is important as parents are the ones responsible for making the decisions about their children's health.[158]

The literature has shown good concordance between parent reported and child reported OHRQoL for most oral health related conditions including dental caries, trauma and orthodontic issues.[194] Although, children cranio-facial anomalies were more likely to rate their OHRQoL higher than their parents.[194] Therefore, while not ideal, given the cognitive and linguist issues of the early childhood, parent assessment as a proxy of child's OHRQoL is acceptable.[158, 194-196]

OHRQoL improvements after intervention

It has been recognised that statistically significant changes in clinical parameters such as the dmft/DMFT index may not be meaningful to a patient.[197] OHRQoL gains of losses, when measured in response to an intervention, can be used to evaluate if the clinical change has significance on

the patient's quality of life. Furthermore, for elective treatments, improvement in OHRQoL can proved evidence that the costs associated with treatment protocols are worthwhile.[125]

There has been a plethora of studies and a number of systemic reviews examining OHRQoL before and after dental rehabilitation in both adults and children, all of which have shown positive changes in quality of life.[144] For example, a large Brazilian study on 1528 children assessed by Child Perception Questionnaire (CPQ 11-14) revealed that treated caries (especially anterior caries) was positively associated with improved OHRQoL.[143] Furthermore, a US study examining 500, 2-8 year old children, before and 6 and 12 months after dental intervention; showed significant improvement in parent reported OHRQoL.[146]

To date, however, there have been no published reports on improvement in OHRQoL after oral health prevention programs.

6.5 Significant findings of the literature review

There are a number of conclusions identified by this review of literature:

1. Dental caries in children is highly prevalent in low socio-economic areas such as Logan-Beaudesert. The caries experience in children can be reduced by prevention strategies such as targeted school based toothbrushing programs. The parameters that influence the effectiveness of school toothbrushing programs are: the baseline caries experience in the community; the level of support offered to the teachers; the long-term sustainability of the program; and the early starting age of the children in the program.
2. The direct effect of water fluoridation on school toothbrushing programs has not been studied but has been hypothesized to mask the effectiveness of the programs due to two main reasons: the baseline caries experience would reduce therefore removing one of the parameters of success of school toothbrushing programs; and children who are already exposed to optimum water fluoridation may have reduced additional benefit from exposure to fluoride from toothbrushing.
3. There has been debate in the literature regarding the effectiveness of low fluoride toothpaste for caries prevention in children. More clinical studies are required to demonstrate the efficacy of fluoride at less then 500 ppm in toothpastes
4. The evaluation of cost effectiveness of prevention programs is vital to the programs' sustained implementation as in today's economic climate limited funds are available for health prevention. The evaluation of OHRQoL gains and losses of a caries prevention programs is important for determining the clinical significance of the intervention to the patient and their family.
5. Multiple instruments have been developed for assessing qualitative OHRQoL, however, there has been no disease specific multi attribute utility instrument developed for quantitative analysis of varying health states for caries in children.

Table 1 Studies assessing supervised toothbrushing at schools published since 2000

Study Country	Study Design	Age	N	SES	Water fluoridation	Study Intervention	Toothpaste strength	Follow up	Study outcome
Macperson et al., 2013 Scotland	cross-sectional epidemiological surveys from 1987-2009	5 years	99,071 records analyzed	variable across the country	no	Analysis of dmft data from national dental survey of five year olds from 1987-2009 to test the effectivness of the daily supervised toothbrushing in nurseries (Childsmile program)	1000ppm	1987-2009	The uptake of the program covered 7% to 25% of the population. The most disadvantaged children showed a greater decrease in mean dmft (4.48 to 2.77) compared with the least disadvantaged children (1.52 to 1.10). For Scotland overall, the mean dmft index decreased from 3.06 to 2.07 (difference = -0.99; 95% CI $p < 0.001$).
Monse et al., 2013 Philippines	longitudinal	mean age 6.6 SD 0.4	168 study 173 control	low	no	Primary school health intervention program involving: 1. daily supervised hand washing with soap and water 2. daily supervised toothbrushing 3. biannual deworming with single dose of albendazole (400mg)	1450ppm	1 year	The study group showed significant increase in BMI (increment of 0.18 study and -0.03 control $p<0.01$) and decrease in soil transmitted helminthes infections (increment -6.5% study and -14.7% control $p<0.001$). There was a reduction in DMFS in permanent first molars which was not statistically significant.
Frazao, 2011 Brazil	RCT	mean age 5.6 SD 0.24	154 study 130 control	low	yes 0.7ppm	Supervised toothbrushing at school compared to 'cross' toothbrushing of permanent molars five times per year by trained dental assistants	1100ppm	18 months	Difference of 21.6 lesions per 1,000 children between control and test groups was observed. Among boys whose caries risk was higher compared to girls, incidence density was 50% lower in test group ($p = 0.016$)
Petersen et al., 2011 China	longitudinal	children in grade 1 (age not disclosed)	404 study 399 control	low	no	Monthly oral hygiene education conducted by teachers who have had attended a 2 day training workshop; Uptake of supervised toothbrushing at school was not reported	not disclosed	3 years	There was no statistical difference between DMFT/ DMFS increments between study and control groups. However there was statistically significant reduction in gingival bleeding scores and children in study group reported better oral health behaviors and knowledge.
Curnow et al., 2008 Scotland	6 year follow up		301 children 65% of children who completed the trial	low	no	After competition of the intervention children were examined at 6, 18, 30, 54, and 78 months a by a single examiner	1000ppm	6 years	6.5 years after the end of the intervention, the children from the intervention group had a mean DMFS increment of 2.72 (SD 3.23), compared to the non-intervention group, with a mean DMFS increment of 3.65 (SD 3.83)
Curnow et al., 2002 Scotland	RCT	mean age 5.3 SD 0.4	239 study 222 control	low	no	Study group had supervised daily toothbrushing and toothbrushes/toothpastes provided for	1000ppm	2 years	Caries increment on newly erupted first permanent molars for study group 0.81 and control group 1.19 (32% reduction $p<0.001$)
Al-Jundy et al., 2005 Jordan	longitudinal	mean age: group 1 - 6.3 SD 0.29 group 2 - 11.7 SD 0.87	436 study 420 control	low	yes 0.5ppm	Study and control groups received OH instructions 30min every day for a week twice a year Study group had supervised school toothbrushing daily	Group 1 = 500ppm; Group 2 = 1000ppm	4 years	dmft for group one study 4.6 SD 3.2 compared to control 5.25 SD 3.2 ($p>0.001$) and group two study DMFT 1.7 SD1.9 and control DMFT 2.0 SD 1.9 ($p>0.001$). Children in control group 1 are 6.4 more likely to develop caries than in study group; and 3.1 for group 2 respectively.
Jackson et al., 2005 England	longitudinal	mean age 5.63 SD 0.33	259 study 258 control	low	no	Supervised toothbrushing at school once a day	1450ppm	21 months	Overall caries increment for study group of 2.6 was significantly less (10.9% $p<0.001$) than the control 2.92. interproximal caries increment differed the most between the study group 0.78 and control group 1.03 (21.4% difference $p<0.01$)
Wind et al., 2005 Netherlands	longitudinal	mean age 7.6 SD 0.6	141 study 155 control	high	no	Supervised toothbrushing at school once a day	not disclosed	2.5 years	At base line children brushed their teeth two times a day in both study and control groups. During intervention children in study group brushed their teeth significantly more often than control groups however this returned to baseline at 12 month follow up. No data on caries experience of either groups was reported
Rong et al., 2003 China	longitudinal	mean age 3 years SD 0.4	258 study 256 control	low	no	Study group received oral health education to teachers every 3 months, to children monthly and for their parents semiannually. Children in the test group brushed their teeth twice daily supervised by teachers. Control group had no intervention	1000ppm	2 years	The reduction in dmfs increment was 30.6% (2.47 study and 3.56 control $p < 0.009$). At the evaluation, a significantly higher percentage of children in the test group than in the control group reported brushing their teeth twice a day (87.6%vs.69.0%;<`0.001). Parents of children in the test group had better oral health knowledge and attitude than controls

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7 SCIENTIFIC PAPER

Caries experience in schools with long-term toothbrushing programs: A controlled retrospective study.

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7.1 Abstract

Background: Primary school toothbrushing program provides excellent opportunity for caries prevention in children living in a low socio-economic-area.

Objective: This retrospective study evaluated a targeted primary school based toothbrushing program conducted in the Logan-Beaudesert area of Queensland, Australia from 2007, to determine its effectiveness in reducing caries.

Methods: Historical (2005-2009) and electronic (2010-2014) records were used to retrospectively analyse caries experience (decayed, missing, filled teeth (dmft/DMFT)) and caries prevalence (proportion of children with caries) in children from two toothbrushing schools (TB) (N=1191) and three non-toothbrushing schools (Non-TB) (N=553), matched socio-economically. Children in all schools were similarly exposed to water fluoridation (1ppm), introduced to the area in 2009.

Results: Post-intervention (2010-2014), at each year level and overall, caries experience (mean dmft/DMFT scores) and prevalence (proportion of children with caries) were lower for TB group than for Non-TB group. The overall mean dmft of TB group (2.53, SD 3.00) was 17% lower ($p<0.001$) than the Non-TB group (3.06, SD 3.30), while the overall mean DMFT of TB group (0.47, SD 1.05) was 59% lower ($p<0.001$) than Non-TB group (1.15, SD 1.72).The overall prevalence of caries in the TB group (68.26%) was 13% lower ($p<0.001$) than in the Non-TB group (78.48%) after 5-9 years of intervention.

Conclusion: A long-term primary school toothbrushing program significantly reduced caries experience and caries prevalence in an optimally fluoridated (1-ppm), very low socio-economic area of Queensland, Australia

7.2 Introduction

Dental caries is one of most challenging conditions in children, with almost half of Australian children experiencing caries by the age of 6 years.[1] The highest prevalence of caries is experienced by low socio-economic communities, immigrant or indigenous populations and medically compromised patients.[2, 3] The Logan-Beaudesert area in Queensland has one of the highest rates of caries in Australia, with over 78% of 6 year old children affected.[1]

Untreated dental caries is associated with considerable morbidity. It can result in chronic pain, difficulty in eating and drinking as well as loss of sleep, behavioural problems and reduced quality of life.[4, 5] Furthermore, untreated carious lesions often progress to oral abscesses which can have serious consequences and are the most common reason for preventable hospital admissions in children.[6]

The cost of treating dental caries is staggering, with the direct cost of over $6 billion dollars, making oral disease the second-most expensive disease group in Australia.[7] Furthermore, the cost of treating early childhood caries is very high as treatment under general anaesthetic (GA) is often required due to the severity of the disease, the necessity for complicated and aggressive dental treatment and the fact that the young child is often uncooperative for treatment in the dental chair.[8, 9] The success of rehabilitation may be questionable, with some children requiring hospitalisation for new lesions as early as six months post GA treatment.[10, 11]

Dental caries is largely preventable,[12] and brushing the teeth with a fluoride toothpaste twice a day remains the most effective caries preventative measure.[13] Toothbrushing delivers its anti-caries effect through mechanical removal of bacteria and disruption of plaque;[14] while fluoride containing toothpaste used during brushing reduces demineralisation and promotes remineralisation,[15] and has a direct anti-bacterial effect.[16]

As children in low socio-economic areas often do not brush their teeth regularly at home,[17] primary school based supervised brushing programs have been recommended by the World Health Organisation as an alternative caries prevention strategy.[18] To date, a number of studies have shown successful reduction in caries through school based toothbrushing programs.[19-22] For

example, a 30 month long Scottish school toothbrushing program, targeting 5 year old children in a disadvantaged, non-fluoridated area showed a 32%-56% reduction in caries affecting the first permanent molar.[20, 23] A 6 year follow up showed a sustained caries reduction of 20%–26%.[21] Likewise, a Jordanian study showed that 6 year old children participating in a school toothbrushing program were six times less likely to develop caries compared to control.[19]

Although several primary school based toothbrushing programs have been reported in Australia,[24, 25] there have been no published studies assessing their effectiveness. The aim of this study is to evaluate a targeted primary school based toothbrushing program conducted in the Logan-Beaudesert area of Queensland, Australia over the past decade, to determine its effectiveness in reducing caries. Moreover, the authors hope that this study will provide a framework for establishing school based toothbrushing programs in other high caries risk areas of Australia.

7.3 Materials and methods

This project has been granted ethical approval from Metro South Human Research Committee (HREC/13/QPAH/663) and from the University of Queensland Institutional Human Research Committee (2014001017).

Background to the toothbrushing program

As previously mentioned, the Logan-Beaudesert area in Queensland is a very low socioeconomic region with high immigrant and transient populations,[2, 3] and has one of the highest rates of caries in Australia.[1] In response to this, a toothbrushing program has been gradually implemented in a number of primary schools in the district since the early 1990's, as part of standard Logan-Beaudesert Oral Health practice. Due to the large number of schools relative to oral health staff in the area, the schools with the highest caries experience and plaque scores in the district, had been selected to participate in the program.

Since implementation, the participating schools have incorporated the program into their daily school hygiene routine. The schools regularly report Information about the program in the school newsletter, and offer the opportunity for parents to opt out. The participating children are provided with a take-home information leaflet for parents, which outlines the school toothbrushing program and gives information on preventative strategies for improving oral health at home.

The toothbrushing programs are conducted by the oral health education team lead by senior oral health therapists. The participating schools receive a start-up lesson for teachers and students at the beginning of each year, conducted by oral health staff. This lesson outlines the rules of the program. The participating children are each provided with a free toothbrush, toothpaste and a storage case; which is kept in their desks. The teacher supervises daily toothbrushing of students for the full school term. The entire class brushes together, at the same time, every day. In order to minimise infection control concerns of needing to rinse after brushing, the children are encouraged to dispense a very small amount of fluoride toothpaste by dipping the toothbrush bristles into the paste. After brushing, the children rinse the toothbrushes with tap water, which are then stored. All years (from prep to year 7) participate in the program. The Australian Dental

Association guidelines are followed for fluoride content of the toothpastes provided to the children,[26] with children in prep year (5 years old) using 500 ppm fluoride toothpaste and the older children using 1000 ppm fluoride toothpaste. The participating schools are audited by oral health therapists yearly for adherence to protocol and for infection control through standardised verbal questioning of teachers and principals.

Clinical examination and caries experience recording by oral health staff

All children attending schools in the Logan Beaudesert area are eligible for free dental services including examination and treatment through Metro South Oral Health. Clinical data relating to dental treatment are collected for every child including caries experience (dmft/DMFT). Oral health staff diagnose and record caries experience, for every child following the WHO recommendations.[27] All oral health staff in the district are provided with training in correct recording of caries experience at the beginning of their employment and are audited twice yearly through clinical documentation audits.

Prior to 2012 all schools in the Logan Beaudesert catchment were visited by school dental vans on a rotational basis (three year recall), where every consenting child was examined by oral health staff. If required, treatment was provided to children, after parental/guardian consent was obtained. Caries experience was recorded in the children's dental records as well as on separate analogue tally sheets relating to the children's schools. The mean dmft/DMFT for every year and school level were calculated without standard deviations and archived at a central location at Kingston Oral Health Centre.

Since 2010, the *Information System for Oral Health* (ISOH) management computer program was introduced to the all the dental clinics in the area, which digitally records each child's caries experience. Since the introduction of this program caries experience data were in digital format.

Data collection

Historical records relating to baseline mean dmft/DMFT for year and school level without standard deviations for toothbrushing (TB) and non-toothbrushing (Non-TB) schools were accessed from archived records kept at the Kingston Oral Health Centre. Post-intervention data were requested

from Queensland Health Information Technology Department and obtained digitally at an individual, de-identified level.

Sample size

Baseline caries prevalence was 78%. To detect caries prevalence of 68% in the TB group with 80% power required 243 children for each group. This was based on using a Chi-squared test with a two-sided 5% significance level. Based on these sample size calculations two TB schools (N=1191) and three Non-TB schools (N=553) were selected from the Logan Beaudesert catchment area. The schools were chosen for their matched socioeconomic status according to the *Index of Relative Socio-Economic Disadvantage* (IRSED),[28] and their close geographic proximity.

Statistical analysis

Baseline comparison between TB and Non-TB groups could be descriptive only as baseline data from historical records were only available in aggregate form (year averages) without standard deviations. Similarly, pre and post intervention data could only be descriptively compared due to the same limitations of the historical baseline records. Post intervention data was available for individual children, therefore TB and Non-TB groups could be compared statistically for mean caries experience (dmft and DMFT scores) with independent t-tests; for caries prevalence (percentage of children with caries) with chi-square tests; and for DMFT increment (caries rate) with Mann-Whitney test due to a severely skewed distribution of scores. The DMFT increment was calculated for each child seen more than once over the post-intervention period (2010-2014), by dividing the change in DMFT score by the number of years between the initial and final visits. When calculating mean caries experience (dmft and DMFT scores) as well as prevalence, only the final values were used for children seen more than once in both TB and Non-TB groups. The data were analysed using the SPSS software package (PASW Statistics 18, IBM , Chicago, IL, USA). The level of significance was set at 0.05.

7.4 Results

Table 1 shows baseline caries experience (mean dmft and DMFT) for TB (N=1756) and Non-TB (N=1800) schools from 2005-2006. Visual inspection of the dmft and DMFT baseline data (Table 1) indicates that mean dmft and mean DMFT values were similar at each year level as well as overall for the TB and the Non-TB groups.

Table 2 outlines caries experience (mean dmft and DMFT) of TB (N=1191) and Non-TB (N=553) schools after toothbrushing had been in the schools from 5 to 9 years. As shown in Table 2 at each year level and overall, mean dmft and mean DMFT scores were lower for the TB group than for the Non-TB group. The overall mean dmft of the TB group was 17% lower than that of the Non-TB group (2.53 vs 3.06, $p<0.001$); and the overall mean DMFT of the TB group was 59% lower than that of the Non-TB group (0.47 vs 1.15, $p<0.001$). Furthermore, when children in the non-TB group reach year 3 (8 years old) their mean DMFT (1.31, SD 1.64) is higher than any other year level in the TB group including year 7 (12 years old) mean DMFT (1.04, SD 1.56).

Figure 1 shows caries prevalence of TB and Non-TB schools post intervention. As shown in Fig. 1, at each year level and overall, the caries prevalence in the TB group was lower than in the Non-TB group. The overall caries prevalence in the TB group was 13% lower than in the Non-TB group (68.3% vs 78.5%, $p<0.001$).

Figure 2 shows DMFT increment (caries rate) of TB and Non-TB schools post intervention. As shown in Fig. 2, there was a significant difference between the TB and Non-TB groups with respect to caries increment ($p<0.001$). The median DMFT increment for both TB and Non-TB groups was 0, but the maximum value for the TB group was lower than that of the Non-TB group (2 vs 4).

7.5 Discussion

It is well established that the aetiology of caries is multifactorial and depends on a complex interplay of biological, physiological, psychological and social factors.[14] Although a multipronged approach to caries prevention is likely to be the most successful, brushing teeth with a fluoride containing toothpaste twice a day still remains the most effective caries preventative measure.[13] Several modes of action of toothbrushing to control caries have been proposed.[14] Firstly, the mechanical nature of toothbrushing acts to remove or reduce bacteria from the tooth surface and disturb the organised nature of dental plaque. [14] Furthermore, toothpastes, which are commonly used during toothbrushing, are vehicles for active ingredients such as fluoride, triclosan and sodium lauryl sulphate, that have been shown to have a number of positive effects including decreasing demineralisation and increasing remineralisation,[15] as well as direct anti-bacterial effects.[16]

The frequency of toothbrushing has been linked with caries experience in children. Brushing a child's teeth twice a day from the age of one year has been reported to double the child's chances of remaining caries free; [29] while children who brush their teeth less than twice a day have a greater likelihood of developing caries within the ensuing twelve months.[29-31] Supervised toothbrushing and parental toothbrushing of child's teeth, increases brushing effectiveness as the child does not have the adequate dexterity skill until the age of nine years.[23, 32]

Although brushing at home twice a day is optimal, many children, particularly in low socio-economic areas, do not do this.[17] School-based interventions not only offer children supervised brushing once a day, they also offer training in a skill that has the potential to be continued in the future, and which may not be taught at home.[33] This was recognized in 2003 by the World Health Organisation, in the "Global School Health Initiative" statement specific for oral health.[18] The WHO rationale behind targeting oral health promotion to school children is that world wide attendance rates for primary schools are high,[34] and thus many children can be reached. Furthermore, schools are an import part of child's socialisation and development, and during the school years lifelong sustainable health related behavior, beliefs and attitudes can develop. [35]

A recent WHO global survey of school-based oral health promotion in 61 countries of various geographic and economic backgrounds, revealed that after oral health education, daily

toothbrushing at schools was the most common intervention used today,[24] and a number of countries have adopted school based toothbrushing as part of national health programs including Brazil[36] and Scotland[37].

Despite the reportedly high uptake of school based toothbrushing programs, to date there have been only seven original studies published examining toothbrushing at schools as the key element of the intervention (one RCT, four longitudinal and one cross-sectional).[19-22, 38-43] Additionally, one study has integrated toothbrushing as part of general health promotion.[44, 45] No Australian study evaluating a toothbrushing program has so far been published in a peer reviewed journal.

The positive findings of our study are supported by four successful programs including the Scottish,[20, 21, 40] UK[22], Chinese[43] and Jordanian[19]. For example, the London study targeted 517 primary school children (mean age 5.6 years) in a non-fluoridated, disadvantaged area with teacher-supervised toothbrushing with fluoride toothpaste (1,400 ppm), reported reductions in caries experience of 11%-21% over the 21 month period compared to control schools.[22] The Chinese study, targeted 258, 3-year-old children in test kindergartens who received monthly oral health education by dental professionals and performed toothbrushing at school two times a day with a 1100 ppm fluoride toothpaste.[43] The study reported a reduction in dmfs increment of 30.6% (dmfs 2.47 in study group and 3.56 in control group $p< 0.009$).

Furthermore, our study supports previous findings that school based toothbrushing programs are particularly effective in low socio-economic areas,[19, 22, 37, 38] where toothbrushing rates at baseline are generally low and caries experience is high.[1, 46] The Logan-Beaudesert area in Queensland is a very low socioeconomic region with high immigrant and transient populations,[2, 3] and has one of the highest rates of caries in Australia, with over 78% of 6 year old children affected.[1]

Conversely, the studies that have shown limited success in reducing caries or limited sustainable effects through toothbrushing at schools have been a Dutch[42] and a recent Chinese[39] intervention. The Dutch study which ran for 3 years involving teacher supervised toothbrushing at schools showed improvement in toothbrushing frequency in 7-10 year old children.[42] However, one year after the intervention the toothbrushing frequency returned to baseline. The study did not measure caries experience. The Chinese study was a three year toothbrushing at school program, which showed significant impacts on gum health, reduced sweet food consumption, increased

parental and teacher oral health knowledge; however it failed to show statistically significant improvement in caries rates.[39] The failure of the study could be attributed to limited uptake of toothbrushing at schools with only half of the children participating.

Both of these studies show that continually sustained support for the toothbrushing program is a key parameter for success of the intervention. This is demonstrated by the Logan-Beaudesert primary school toothbrushing program of the present study as it has been continued for almost a decade, with on-going support for the teachers from the oral health staff.

The key limitation of this study's Logan-Beaudesert toothbrushing program, from a research perspective, is that it was not originally established as a prospective trial. Therefore only retrospective analysis of previously collected data can be performed in order to evaluate its effectiveness. As baseline caries experience for each individual child and standard deviations were not available, only descriptive analysis of baseline data as well as comparison between baseline and post-intervention data was possible. Nonetheless, visual inspection of baseline data indicates that the caries experience between TB and Non-TB groups was comparable (Table 1). This finding is not unexpected as the schools were matched by geographic location and SES status.
Furthermore, it is important to note that the delivery of Oral Health Services in the district changed drastically during the study period. At baseline, almost every child attending a primary school in the district was examined on rotational basis in school dental vans, however, since 2010 there had been a shift to a centralised family model of care where parents are required to make an appointment and attend with their child at one of the dental clinics in the area. Mandatory parental attendance, in conjunction with oral health services not located on site at school could explain the smaller number of children who have accessed oral health services and thus the large sample size differences between baseline (Table 1) and post-intervention (Table 2) data as well as the higher caries experience reported in both TB and Non-TB groups post-intervention (Table 2) compared to baseline (Table 1). However, these variables and cofounders in data sets are consistent across both the TB and Non-TB groups and therefore are unlikely to affect the reported impact of the intervention.

On the other hand, it has been previously argued that that the toothbrushing school programs are most successful in areas without optimum water fluoridation, as non-fluoridated areas are expected to have higher caries experience and therefore be relatively more responsive to

preventative programs.[25] However, our study shows significant differences in caries experience, prevalence and DMFT increment (Table 2 and Fig 1 and 2 respectively) in favor of TB versus Non-TB schools, despite optimum water fluoridation of 1 ppm being introduced mid-intervention in 2009.

In conclusion, a long-term primary school toothbrushing program significantly reduced caries experience, caries prevalence and DMFT increment in an optimally fluoridated (1-ppm), very low socio-economic area of Queensland, Australia

7.6 Tables

Table 1 Baseline caries experience (dmft and DMFT) prior to intervention from 2005 to 2006 in toothbrushing and non-toothbrushing schools

Year (Mean Age) N = 3556	N (%)		Mean dmft		Mean DMFT	
	TB N = 1756	Non-TB N =1800	TB N = 1756	Non-TB N =1800	TB N = 1756	Non-TB N =1800
Prep (5y)	129 (7.3)	158 (8.8)	2.34	1.75	0.02	0.00
Year 1 (6y)	223 (12.7)	286 (15.9)	2.93	2.89	0.13	0.13
Year 2 (7y)	237 (13.5)	225 (12.5)	3.04	2.80	0.35	0.43
Year 3 (8y)	242 (13.9)	225 (12.5)	2.55	2.76	0.57	0.78
Year 4 (9y)	238 (13.6)	246 (13.7)	2.71	2.26	1.00	0.72
Year 5 (10y)	225 (12.8)	209 (11.6)	2.33	1.91	1.06	1.14
Year 6 (11)	214 (12.2)	235 (13.1)	1.20	1.63	1.07	1.62
Year 7 (12)	248 (14.1)	216 (12.0)	0.66	0.72	1.40	1.67
Total	1756	1800	2.23	2.14	0.74	0.81

dmft – decayed, missing, filled teeth score in the primary dentition

DMFT – decayed, missing, filled teeth score in the permanent dentition

TB – toothbrushing schools

Non-TB – non-toothbrushing schools

Table 2 Post-intervention caries experience (dmft and DMFT) from 2010 to 2014

Year (Mean Age) N = 1744	N (%)		Mean dmft (SD)		TB v Non-TB p value*	Mean DMFT (SD)		TB v Non-TB p value**
	TB N= 1191	Non-TB N= 553	TB N=1191	Non-TB N=553		TB N=1191	Non-TB N=553	
Prep (5y)	133 (11.2)	65 (11.6)	3.38 (4.03)	4.98 (4.42)	0.01	0.06 (0.42)	0.02 (0.12)	0.40
Year 1 (6y)	174 (14.6)	62 (11.2)	2.96 (3.30)	4.19 (3.73)	0.02	0.08 (0.41)	0.24 (0.74)	0.04
Year 2 (7y)	172 (14.4)	69 (12.5)	2.83 (3.17)	3.43 (3.16)	0.18	0.35 (0.88)	0.90 (1.44)	<0.001
Year 3 (8y)	162 (13.6)	85 (15.4)	3.03 (2.86)	4.04 (3.18)	0.01	0.46 (1.03)	1.31 (1.64)	<0.001
Year 4 (9y)	217 (18.2)	67 (12.1)	2.66 (2.66)	3.69 (2.86)	0.01	0.63 (1.10)	1.25 (1.54)	<0.001
Year 5 (10y)	179 (15.0)	56 (10.1)	2.11 (2.57)	2.73 (2.40)	0.11	0.64 (1.12)	1.75 (1.74)	<0.001
Year 6 (11)	103 (8.6)	80 (14.5)	1.25 (1.85)	1.21 (1.79)	0.88	0.94 (1.60)	1.55 (1.88)	0.02
Year 7 (12)	51 (4.3)	69 (12.5)	0.39 (0.98)	0.46 (1.15)	0.72	1.04 (1.56)	2.09 (2.40)	0.01
Total	1191	553	2.53 (3.00)	3.06 (3.30)	<0.001	0.47 (1.05)	1.15 (1.72)	<0.001

dmft – decayed, missing, filled teeth score in the primary dentition

DMFT – decayed, missing, filled teeth score in the permanent dentition

TB – toothbrushing schools

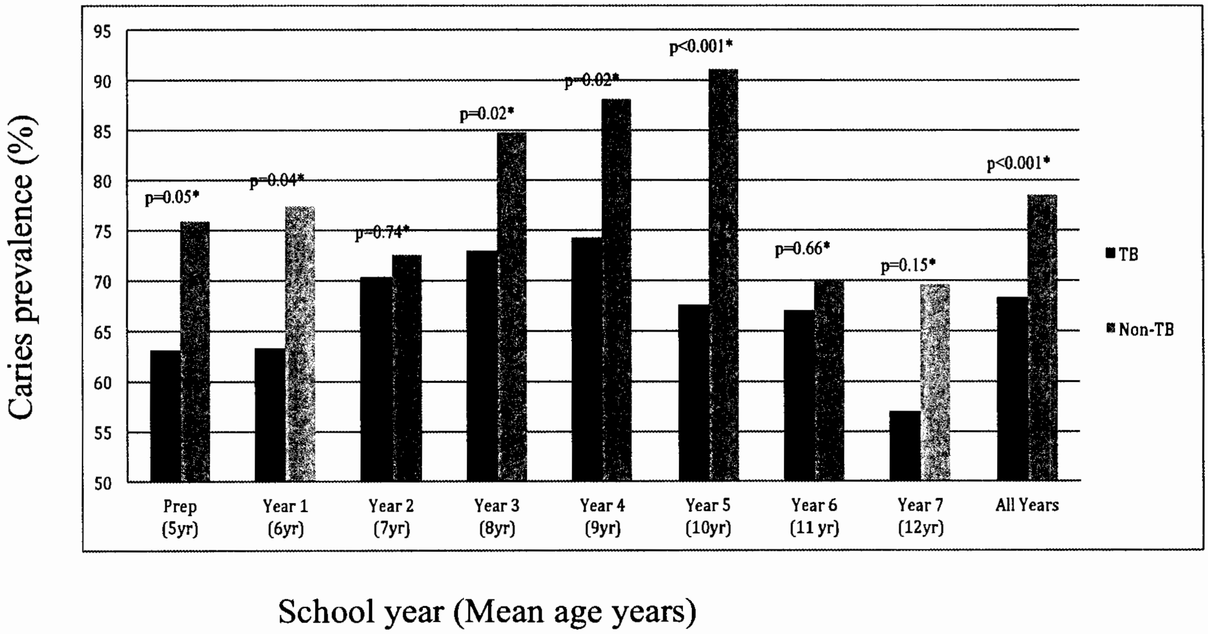
Non-TB – non-toothbrushing schools

*t-test comparing caries experience in the primary dentition of toothbrushing versus non-toothbrushing schools

** t-test comparing caries experience in the permanent dentition of toothbrushing versus non-toothbrushing schools

7.7 Figures

Figure 1 Post-intervention caries prevalence (%) from 2010 to 2014

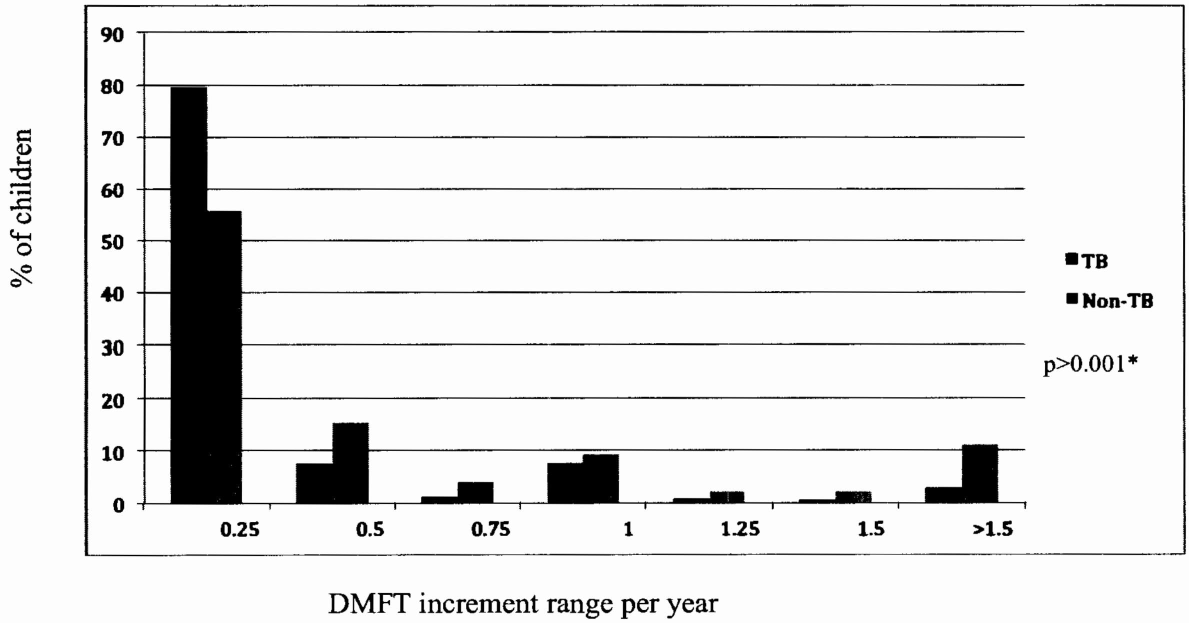


TB – toothbrushing schools

Non-TB – non-toothbrushing schools

*Chi-square test comparing caries prevalence in toothbrushing versus non-toothbrushing schools

Figure 2 Post-intervention annual caries increment (DMFT) from 2010 to 2014



TB – toothbrushing schools

Non-TB – non-toothbrushing schools

DMFT increment (caries rate) was calculated for each child seen more than once over the post-intervention period from 2010 to 2014 by dividing the difference in initial and final DMFT score by the number of years in between visits

*Mann-Whitney non-parametric test comparing DMFT increment of toothbrushing versus non-toothbrushing groups

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